(19) Japan Patent Office (JP)

(11) Patent Application Publication No.

S62-189770

(12) Patent Application Publication (A)

(43) Publication Date: Aug. 19, 1987

(51) Int. Cl.^{4}	Classification symbol	Internal reference No.
H 01 L 33/00		A-6819-5F
H 01 S 3/18		7377-5F

Examination request: Requested

Number of Inventions: 1 (Total 5 pages)

---

(54) Invention Title:

Junction-Type Light Emitting Semiconductor Device

(21) Application No.: S61-31573

(22) Application Date: Feb. 15, 1986

(72)	Inventor:	Fumio Inaba	1-13-1 Yagi-sann Minami, Sendai-shi
(72)	Inventor:	Hiroaki Ito	390-82 Aza-Aoba, Aramaki, Sendai-shi
(72)	Inventor:	Akira Mizuyoshi	c/o Itami Works, Dainichi Nihon Densen Co., LTD 4-3 Ikejiri, Itami-shi
(71)	Applicant:	Fumio Inaba	1-13-1 Yagi-sann Minami, Sendai-shi
(71)	Applicant:	Hiroaki Ito	390-82 Aza-Aoba, Aramaki, Sendai-shi
(71)	Applicant:	Mitsubishi Densen Co., LTD.	3-Banchi, Nishinoshima, Higashimukoujima, Amagasaki-shi
(74)	Agent:	Patent Attorney:	Hajime Takashima

Specification

1. Invention Title:

Junction-Type Light Emitting Semiconductor Device

2. What is Claimed is:

A junction-type light emitting semiconductor device which is equipped with a flat plate section, a pillar protrusion which is provide on one surface of said flat plate section, and electrodes which are provided on any location of the flat plate section and the pillar protrusion; and which has a pn junction extending at least within the pillar protrusion along a direction perpendicular to the flat plate section; wherein a phosphor layer is provided on a top surface of the pillar protrusion and covers at least a portion of an emission section including the pn junction which is exposed on said top surface.

3. Detailed Explanation of the Invention

{Field of Industrial Application}

The present invention relates to a junction-type light emitting semiconductor device which can be employed in a light emitting diode and semiconductor laser. In particular, the present pertains to a junction-type light emitting semiconductor device which is equipped with a flat plate section, a pillar protrusion which is provide on one surface of said flat plate section, and electrodes which are provided on any location of the flat plate section and the pillar protrusion; and which has a pn junction extending at least within the pillar protrusion along a direction perpendicular to the flat plate section; wherein the wavelength of an emission from an emission section including the pn junction is converted.

{Conventional Technologies}

A light emitting device which provides an emission in a direction perpendicular to its substrate (flat plate section) can be easily coupled to an optical fiber. Moreover, when such devices are arranged in a one or two dimensional array, various applications can be

expected in OA (Office Automation) information apparatuses and the like. Therefore, researches are being conducted for its development in laboratories for semiconductor lasers and light emitting diodes. In recent years, various types were put to practical use.

{Issues to be Resolved by the Invention}

A basic structural example of a junction type light emitting semiconductor device whose pn junction within a pillar protrusion formed along a direction perpendicular to its substrate provides an emission in a direction perpendicular to the substrate consists of a flat plate section (B), a pillar protrusion (P) which is provided on one surface of the flat plate section, a p-side electrode (E1) which is provided on a side periphery of pillar protrusion (P) and on an upper surface of flat plate section (B), and an n-side electrode (E2) which is provided on a bottom surface of flat plate section (B), as illustrated in Figure 4. Through pillar protrusion (P), there exists a pn junction PN1 which extends in a direction perpendicular to flat plate section (B), and through flat plate section (B), there exists a pn junction PN2 which extends in a direction parallel to said flat plate section (B). The structure is designed so that a current is injected between electrodes (E1) and (E2) so that an emission in a perpendicular direction can be obtained. Such a light emitting device principally excels in emission collection efficiency when it is compared to conventional devices with a structure for emitting in a direction parallel or perpendicular to the flat plate section. Such a light emitting device can be coupled with an optical fiber with good efficiency.

Meanwhile, most of such light emitting devices are made of gallium arsenide (GaAs) because of their purpose to emit light. The first reason for employing GaAs is that source materials are inexpensive and can be stably supplied and the second reasons is that reactive ion etching and reaction ion beam etching can be readily performed.

However, GaAs has a narrow band gap and its emission wavelengths are 0.91 ~ 0.98 microns, which are long, and thereby provides infrared radiations. Therefore, its emission is not visible to human. Thus, there is no problem when light emitting devices made of GaAs are employed as light emitting diodes or semiconductor lasers. When such light emitting devices are arranged in a one- or two-dimensional array structure and employed in a display apparatus, however, it is necessary to convert their emissions to

visible ones. In the current state of progress, such light emitting devices equipped with a concrete means are not yet provided.

Thus, the purpose of the present invention is to provide a junction-type light emitting semiconductor device in which the wavelength of an emission from an emission section is converted so that one or a plurality of such devices in an array form can be employed to a display apparatus.

{Means to Resolve the Issues}

The above purpose is accomplished by a junction-type light emitting semiconductor device which is equipped with a flat plate section, a pillar protrusion which is provide on one surface of said flat plate section, and electrodes which are provided on any location of the flat plate section and the pillar protrusion; and which has a pn junction extending at least within the pillar protrusion along a direction perpendicular to the flat plate section; wherein a phosphor layer is provided on a top surface of the pillar protrusion and covers at least a portion of an emission section including the pn junction which is exposed on said top surface.

Further, the principal purpose of a junction type light emitting semiconductor device such as the one described above is to obtain an emission from the pn junction (pn junction PN1) which extends in a direction perpendicular to a flat plate section. It is preferred to implement various techniques so that there is no pn junction (pn junction PN2) which extends in a direction parallel to the flat plate section, or so that even if it exists, it does not provide an emission. As an example of such technique, when a pn-junction is formed in a pillar protrusion and a flat plate section, a mask can cover the top surface of the flat plate section during impurity diffusion. Then, a junction type light emitting semiconductor device which does not essentially have a pn junction PN2 which extends within the flat plate section in a direction parallel to the flat plate section can be obtained. In the present invention, a junction type light emitting semiconductor device with such a structure is preferably employed.

Moreover, a phosphor layer is for converting the wavelength of an emission form an emission section within a pillar protrusion, in other words wavelengths of 0.91 ~ 0.98 microns in the case of GaAs which is often employed as a material for such a pillar

protrusion. It is necessary to employ a phosphor which can be excited by a radiated emission (infrared radiation in the case of GaAs) and emits light. As for a phosphor to convert an emission to visible light, $Y_{0.74}Yb_{0.25}Er_{0.01}OCl$ (emission wavelength of 0.66microns) can be employed as an example for a red emission among visible ones, $Y_{0.84}Yb_{0.15}Er_{0.01}F_3$ (emission wavelength of 0.55microns) can be employed for a green emission, and $Y_{0.65}Yb_{0.35}TM_{0.001}F_3$ (emission wavelength of 0.47microns) can be employed for a blue emission. A proper phosphor can be selected for a different application.

{Operation}

A junction type light emitting semiconductor device of the present invention employs a phosphor layer which is provided on a top surface of a pillar protrusion to convert the wavelength of an emission from a GaAs active layer.

{Embodiments}

Below, examples of a junction type light emitting semiconductor device of the present invention are explained while referencing figures.

Figures 1 and 2 depict an example of a junction type light emitting semiconductor device of the present invention. The junction type light emitting semiconductor device in this example utilizes GaAs as its material. The emission from GaAs is converted into a visible one so that the devices can be employed in a display apparatus and the like. Any of the above examples can be utilized as a phosphor. As is obvious in the figures, the light emitting device was equipped with a flat plate section (B) having a double layer structure consisting of a substrate (B1) and a top section layer (B2), a pillar protrusion (P) which was provided on one surface of flat plate section (B), a p-side electrode (E1) which was provide on a side periphery of pillar protrusion (P) and a top surface of flat plate section (B), an n-side electrode (E2) which was provided on a bottom surface of flat plate section (B), an SiO_2 layer (5) which was formed on the entire top surface of pillar protrusion (P), and a phosphor layer (7) which was provided on SiO_2 layer (5), and an insulator layer (10) which was provided between the top surface of flat plate section (B) and electrode (E1). Within pillar protrusion (P), a cylindrical pn junction PN1 was

formed and extended in a direction perpendicular to flat plate section (B). Within flat plate section (B), however, a pn junction PN2 extending in a direction parallel to said flat plate section (B) was not formed. Therefore, when an electric current was injected between electrodes (E1) and (E2), pn junction essentially provided an emission solely in a direction perpendicular to flat plate section (B). Moreover, providing insulator layer (10) prohibits a current from flowing from electrode (E1) on the top surface of flat plate section (B) to electrode (E2) through flat plate section (B) along its vertical direction. Thus, the injection efficiency of current flowing from electrode (E1) on the side periphery of pillar protrusion (P) through pn junction PN1 to electrode (E2) can be enhanced.

In the light emitting device structure, phosphor layer (7) to convert the wavelength of an emission from the emission section within pillar protrusion (P) to another wavelength covers the light emission section exposed on the top surface of pillar protrusion (P) and is provided on SiO2 layer (5) formed on the entire top surface of pillar protrusion (P). Thus, the infrared emission can be converted into visible light. Therefore, when the light emitting devices are arranged in a one- or two-dimensional array structure, a precise display apparatus such as those in OA information apparatuses and the like and these devices are very important in terms of practical applications.

Next, an example of production method of a light emitting device with a structure depicted in Figure 1 is briefly explain for a case in which GaAs is employed as a substrate, in which AlGaAs is epitaxially grown on the substrate and in which the wavelength of an emission form AlGaAs is converted to visible light.

First, on an n-type GaAs substrate (B1), an n-type AlxGa1-xAs epitaxial layer for a pillar protrusion (P) was grown. The epitaxial layer was etched using a reactive ion etching method and a pillar protrusion (P) was formed. The remaining section of the epitaxial layer after forming said pillar protrusion (P) became a top section layer (B2) as illustrated in the figure. Top section layer (B2) is not absolutely necessary. A pillar protrusion (P) can be formed by etching through part of substrate (B1). Next, a mask covered the top surface of pillar protrusion (P) and the surface of top section layer (B2) while exposing the side periphery of pillar protrusion (P). Then, a p-type impurity

(preferably zinc) was diffused to form a cylindrical pn junction PN1 within pillar protrusion (P).

After the diffusion process, a p-side electrode (E1) was formed on the side periphery and the top surface of pillar protrusion (P) and on the top surface of top section layer (B2), and an n-side electrode (E2) was formed on the bottom surface of substrate (B1). Then, unnecessary portions of the electrode materials and mask layer were removed using a lift-off method, thereby producing a junction-type light emitting semiconductor device which can be utilized as a light emitting diode which has only pn junction PN1 extending within pillar protrusion (P) in a direction perpendicular to substrate (B1), but not a pn junction PN2 in flat plate section (B).

After producing the light emitting device, a desired phosphor among the aforementioned ones which convert an emission to visible light can be applied on the top surface of pillar protrusion (P). Then, a junction-type light emitting semiconductor device having a phosphor layer (7) which can convert an emission wavelength to another as illustrated in Figure 1 can be produced.

In the aforementioned example of light emitting device, an epitaxial layer made of the same material as the substrate was grown on the substrate. However, a substrate alone can be employed for light emitting devices. It is, however, preferred that an epitaxial layer be provided in order to obtained an even more powerful emission. Moreover, a phosphor layer (7) does not need to be formed on the entire top surface of a pillar protrusion (P). When a phosphor layer covers at least a portion of the emission section exposed on the top surface, the wavelength of an emission can be converted. Prom the view point of conversion efficiency, however, it is preferred that a phosphor layer be provided to cover the entirety of the emission section. Further, it is not necessary to provided a phosphor layer (7) on an SiO_2 layer (5) which is formed on the top surface of a pillar protrusion (P). It may be formed directly on the top surface of a pillar protrusion (P).

Figure 3 illustrates a light emitting device in which the above items are taken into consideration. In the light emitting device of this example, a phosphor layer (7) was not formed on an SiO_2 layer (5) and is not provided on the entire top surface of a pillar protrusion (P). I only covers the emission section which was exposed on the top surface.

A flat plate section (B) was made of solely a substrate. Pillar protrusion (P) was formed from the substrate. The other conditions were the same as in the case of the light emitting device depicted in Figure 1. The emission from the emission section can be converted to visible light.

In the present invention, positions and size of electrodes (E1) and (E2) are not limited to those illustrated in the examples. The electrode can be formed at any location with any size. Moreover, there are no particular limitations for a formation method of a pn junction. For example, an impurity diffusion method, a vapor phase epitaxial growth method of a p- (or n-)type semiconductor layer and an n- (or p-)type semiconductor layer, or other methods can be employed.

In the present invention, the length of a pn junction PN1 which contributes to the vertical emission can be made longer by making a pillar protrusion (P) taller. Therefore, it is preferred that the height of a pillar protrusion (P) be at least 2 microns and more preferred that it be at least 10 microns. A pillar protrusion (P) can be formed on a surface of a semiconductor wafer employing, as an example, a reactive ion etching method. Thereby, a light emitting device of the present invention having a pillar protrusion (P) with a height of a few tens to a few hundreds of microns can be fabricated with ease.

In the present invention, a pillar protrusion (P) being in a "direction perpendicular" to a flat plate section (B) does not need to be restrictively interpreted as being a 90 degrees angle to flat plate section (B). An angle a little larger or smaller than 90 degrees with respect to a substrate can be included. For example, a pillar protrusion (P) itself, or solely a concentrically cylindrical pn junction PN1 formed therein can be made in a form of a truncated cone with a larger diameter on the bottom, so that the output emission can be focused for an easier coupling to an optical fiber. Alternatively, a reverse truncated cone which is opposite of the above can be employed for a diversion as necessary for an application.

Examples of emission materials which can be employed in a junction type light emitting semiconductor device of the present invention include III-V compound semiconductors such as GaAs, GaP, AlGaAs, InP and InGaAsP, II-VI compound semiconductors such as ZnSe, ZnS, ZnO, CdSe and CdTe, IV-VI compound semiconductors such as PbTe, PbSnTe and PbSnSe, and further IV-IV compound

semiconductors such as SiC. Advantages of each material can be taken into consideration for application.

{Advantages of the Invention}

As is obvious from the above, in a junction type light emitting semiconductor device of the present invention, a phosphor layer covers at least part of the emission section including a pn junction exposed on the top surface of a pillar protrusion extending in a direction perpendicular to a flat plate section and having a pn junction. Thus, the wavelength of an emission from the emission section can be converted to another. For example, when a phosphor layer made of a phosphor to convert an emission to visible light, the emission can be visible to human. Therefore, an array structure of such devices can produce precise display apparatus and the like. Such a device is very useful in practical applications.

4. Brief Explanation of Figures

Figure 1 is an angled view of an example of a junction type light emitting semiconductor device according to the present invention. Figure 2 depicts a cross section of the light emitting device in Figure 1. Figure 3 is a cross section of another example of a junction type light emitting semiconductor device according to the present invention.

(B)	Flat plate section	(5)	SiO_2 layer
(B1)	Substrate	(7)	Phosphor layer
(B2)	Top section layer	(10)	Insulator layer
(P)	Pillar protrusion	(E1) and (E2)	Electrode
(PN1) and (PN2)	pn Junction		

Patent Applicant: Fumio Inaba

Patent Applicant: Hiroaki Itto

Patent Applicant: Dainichi Nihon Densen Co., LTD

Agent: Patent Attorney: Hajime Takashima

Figure 1

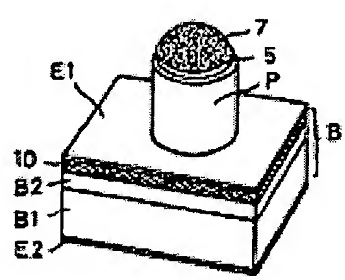


Figure 4

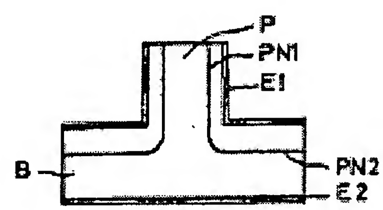


Figure 3

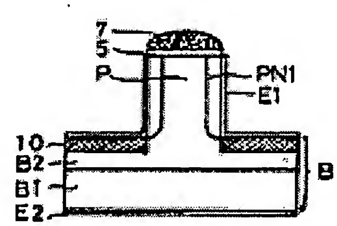
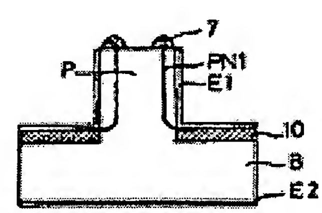


Figure 3



Amendment

April 26, 1986

To: Patent Office Commissioner

1. Case Identificaiton

   Patent Application No. S61-031573

2. Invention Title

   Junction Type Light Emitting Semiconductor Device

3. Those who make the Amendment

Relationship to the Case: Patent Applicants

Names: Fumio Inaba

Hiroaki Ito

Dainichi Nihon Densen Co., LTD

4. Agent

Address: No. 406 New Life Hiranomachi

4-53-3 Hiranomachi, Higashi-ku, Osaka

Tel: 06-227-1156

Takashima International Law Office

Name: Patent Attorney: (8079) Hajime Takashima

5. Amendment Date:

April 22, 1986 (submission date)

6. What is to be Amended.

"Document to verify representative right" and "Brief Explanation of Figures in Specification."

7. Contents of Amendment

(1) A power of attorney is submitted as attached.

(2) Insert "Figure 4 is a cross section of an ordinary junction type light emitting semiconductor device" in the last sentence of "Brief Explanation of Figures."

8. List of Attachments

(1) Power of Attorney 1 copy